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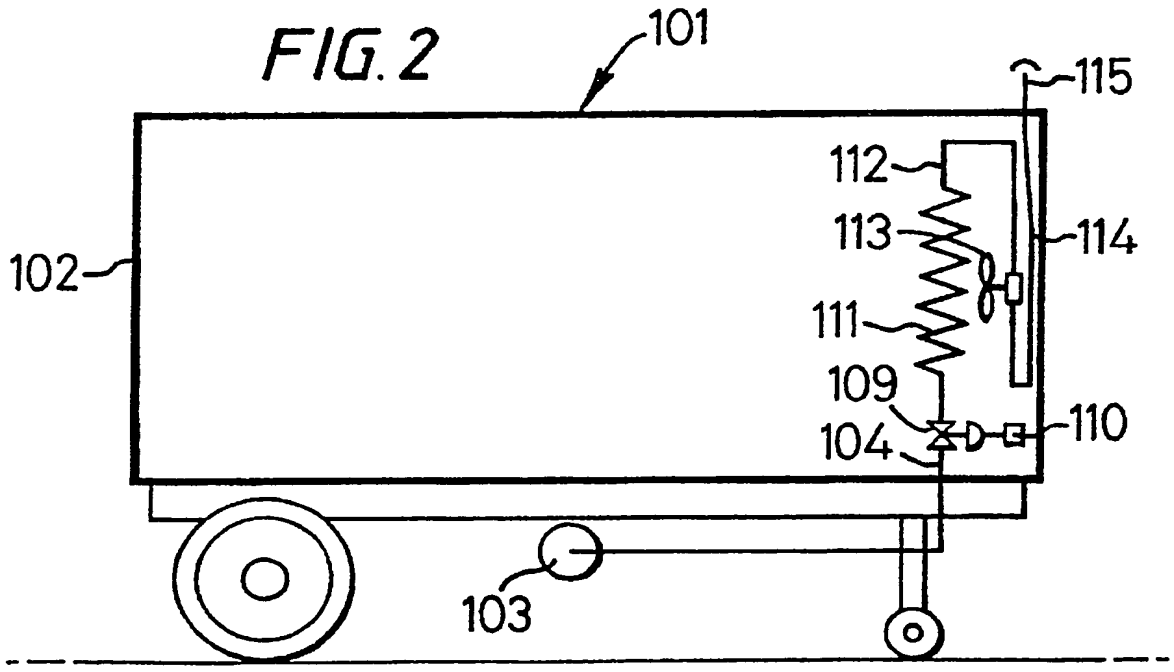
(54) Refrigeration system for cooling a container

(57) A container (102) is cooled by evaporating liquid nitrogen from a vessel (103) in a heat exchanger (111) inside the container (102). A fan (113) blows air over the heat exchanger (111) to ensure that the internal temperature of the container (102) is substantially uniform throughout. The fan (113) is driven by expanding nitrogen vapour from the downstream end of the heat exchanger (111). The expanded nitrogen is vented externally of the container (102) so that an asphyxiating atmosphere is not created inside the container (102).

FIG. 2



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 1

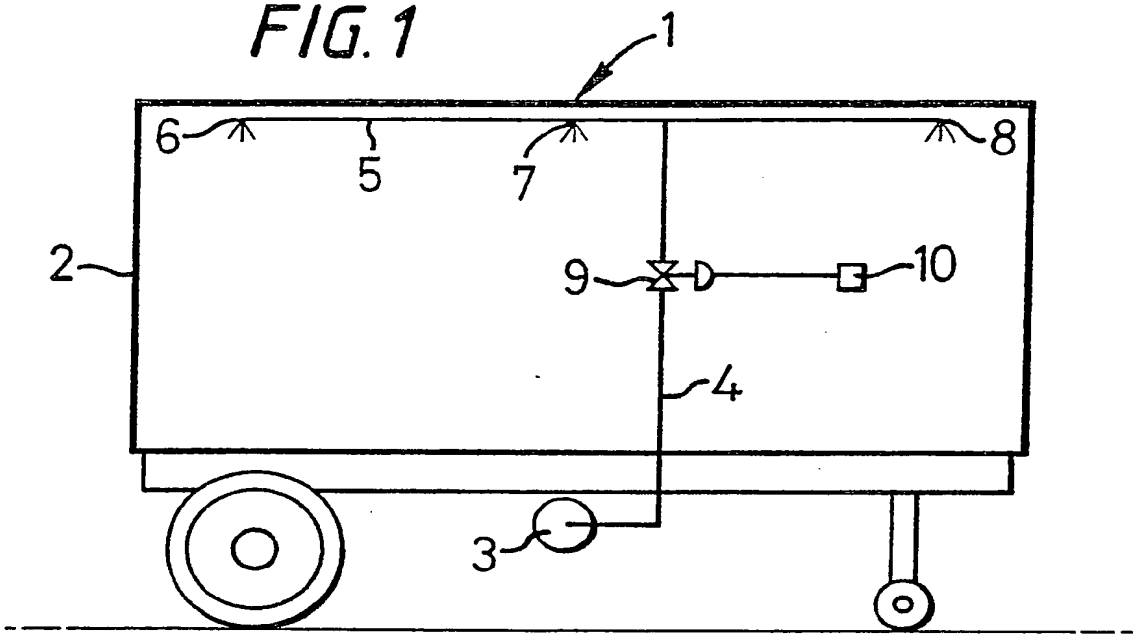

FIG. 2

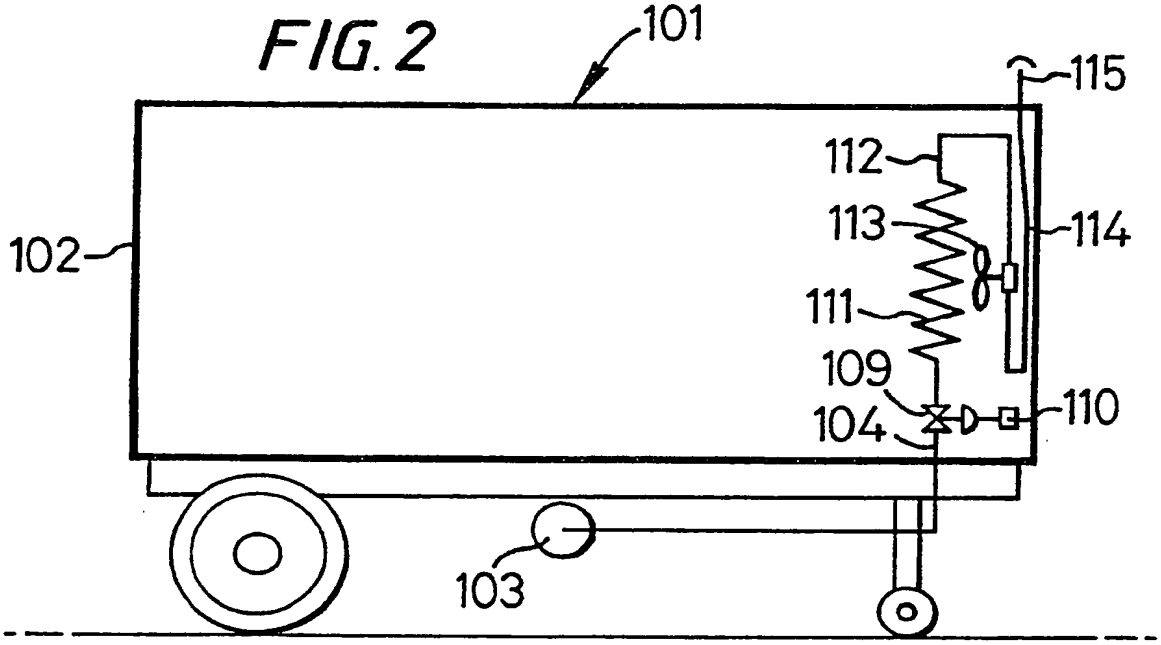

FIG. 3

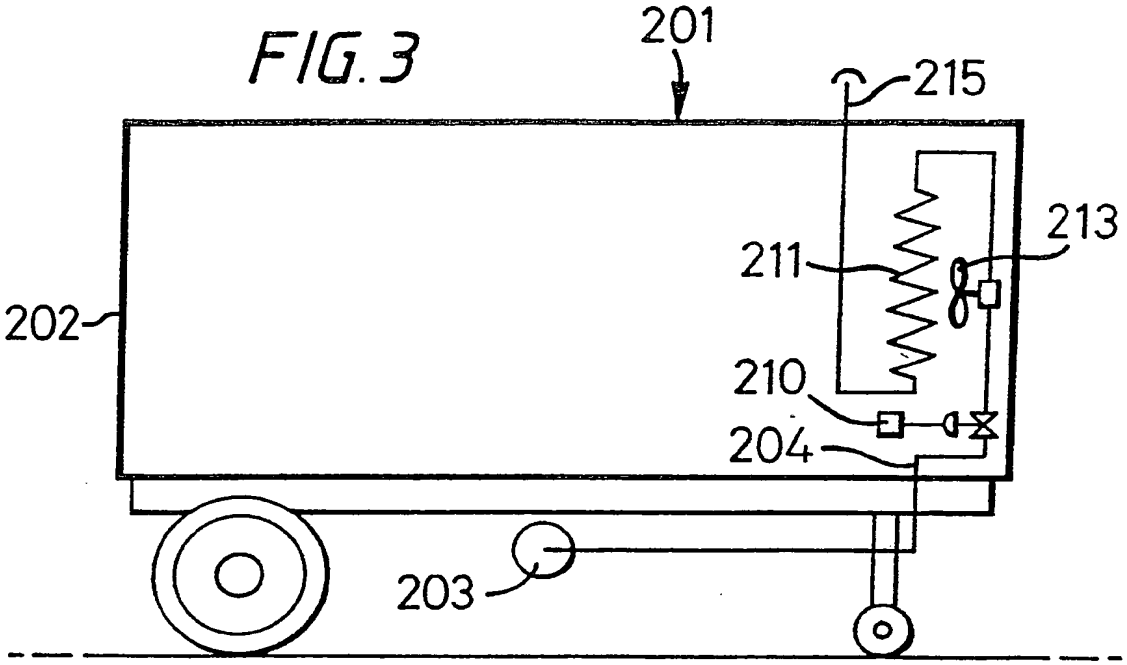
201
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FIG. 4

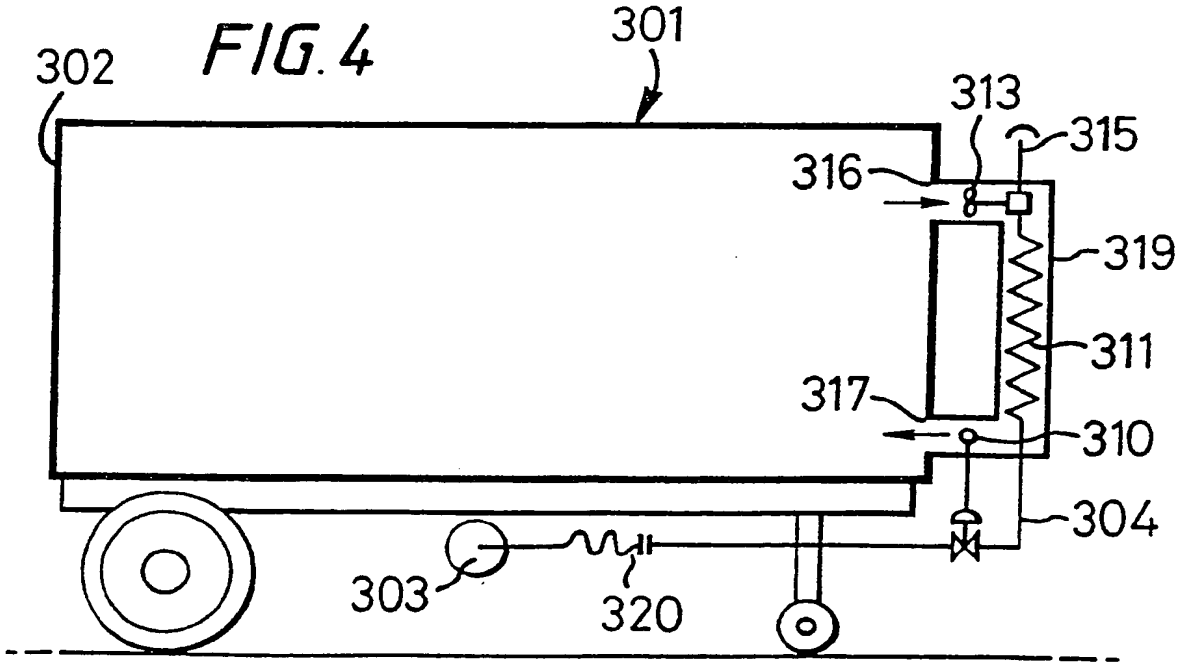
302
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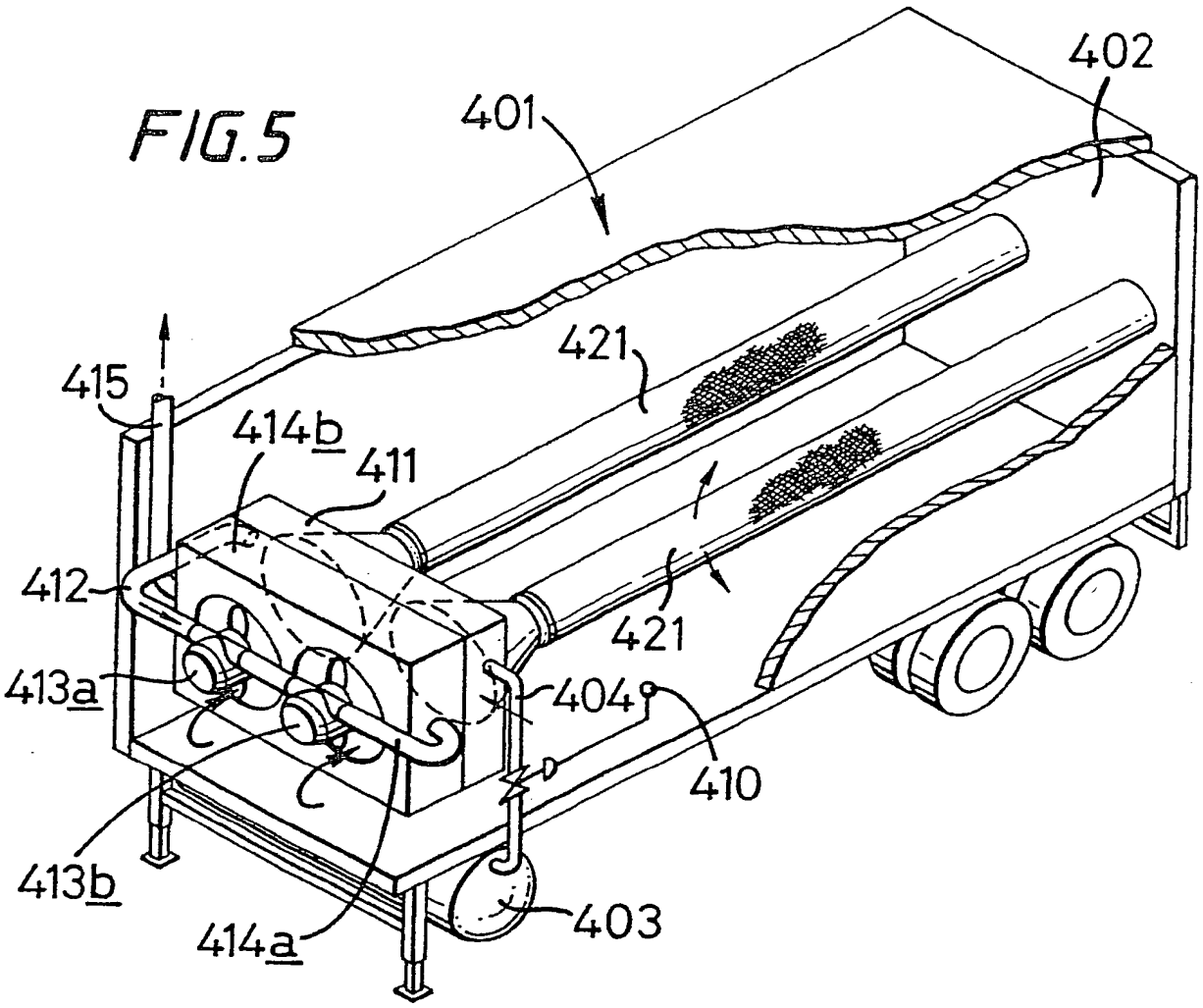
FIG.5


401
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414b
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413a
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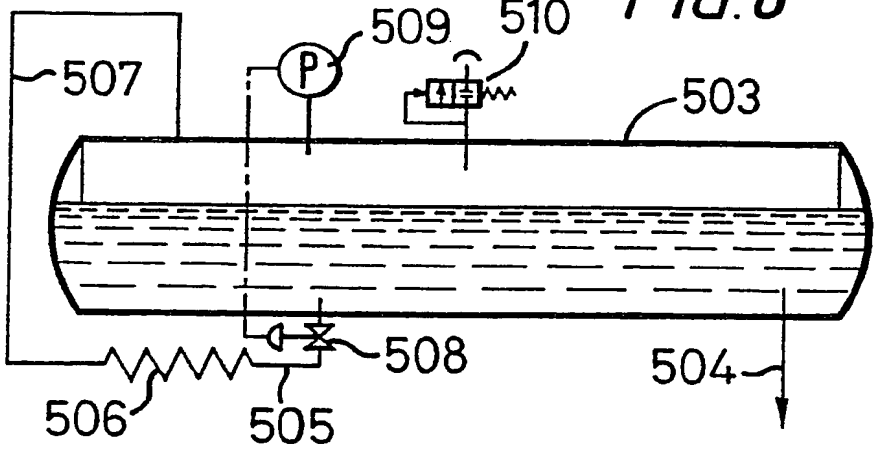
403
414a

FIG.6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REFRIGERATION SYSTEM

This invention relates to a refrigeration system.

Conventionally, containers holding perishable foodstuffs are kept cool by either mechanical refrigeration units or by spraying liquid nitrogen into the container.

Mechanical refrigeration units are relatively expensive to buy and noisy to run. Furthermore, they have a relatively slow initial cool-down period. In contrast liquid nitrogen cooling offers comparatively low capital expenditure, relatively fast cool-down and very quiet operation.

The disadvantage with injecting liquid nitrogen into a container is that the concentration of nitrogen in the container often produces an asphyxiating atmosphere and consequently it is necessary to take stringent safety precautions each time the container is opened to ensure that staff loading and unloading the container are not asphyxiated.

According to the present invention there is provided a refrigeration system comprising a container, a vessel for holding liquid nitrogen, a fan for circulating air within said container, and a first heat exchanger, wherein said first heat exchanger is connected to said vessel and said fan is arranged to be driven by said nitrogen, and wherein means are provided to vent nitrogen externally of said container.

It will be appreciated that since nitrogen is not sprayed into the container there is no formation of an asphyxiating atmosphere within the container and hence the previously required safety precautions can be dispensed with. In addition, since the fan is driven by the expansion of nitrogen no additional power source is required. Indeed, the expansion of the nitrogen may cause the temperature of the nitrogen to drop and the

thus cooled nitrogen may be used to further cool the container.

In one embodiment the fan is arranged to be driven by nitrogen leaving the downstream end of the first heat exchanger.

Advantageously, the refrigeration system includes a second heat exchanger arranged to receive nitrogen from said fan.

Preferably, said fan is arranged to pass air through said second heat exchanger and then through said first heat exchanger.

In another embodiment the fan is arranged to be driven by nitrogen flowing from the vessel to the heat exchanger.

The first heat exchanger may be disposed in the container or in a separate enclosure communicating with the container.

If desired, the fan can be arranged to draw air from outside the container into the container. However, it is preferably arranged to recirculate air within the container.

Advantageously, the refrigeration system includes an evaporator, a pipe for conveying liquid nitrogen from said vessel to said evaporator, a pipe for conveying vaporised nitrogen from said evaporator to said vessel, and means for controlling the flow through the said evaporator.

Preferably the means comprises a flow control valve operable in response to a pressure sensor mounted on said vessel.

For a better understanding of the present invention and to show how the same may be carried into effect reference will now be made, by way of example, to the accompanying drawings, in which:-

Fig. 1 is a schematic side view of a known refrigeration apparatus;

Fig. 2 is a schematic side view of a first embodiment of a refrigeration apparatus in accordance with the present invention;

Fig. 3 is a schematic side view of a second embodiment of a refrigeration apparatus in accordance with the present invention;

Fig. 4 is a schematic side view of a third embodiment of a refrigeration apparatus in accordance with the present invention;

Fig. 5 is a schematic perspective view of a fourth embodiment of a refrigeration apparatus in accordance with the present invention; and

Fig. 6 is a schematic cross-section showing an arrangement for pressurising the liquid nitrogen.

Referring to Figure 1 of the drawings, there is shown a known refrigeration system which is generally identified by reference numeral 1. The refrigeration system 1 comprises a container 2 which is adapted to be connected to a tractor unit (not shown).

A vessel 3 for holding liquid nitrogen is supported beneath the container 2 and is connected by a pipe 4 to a spray bar 5 having a plurality of spray nozzles 6, 7 and 8 disposed along the container 2 adjacent the ceiling thereof.

A control valve 9 is mounted in the pipe 4 and is operated in response to the temperature sensed by a probe 10.

In use, when the temperature sensed by probe 10 is higher than a predetermined level control valve 9 is

opened to allow liquid nitrogen to pass along pipe 4 and spray bar 5 and spray into the container 2 until the temperature is reduced to the desired level.

It will be appreciated that over a period of time the concentration of nitrogen in the container 2 increases to a level which will not support respiration. Accordingly, when the container 2 is opened it is necessary to leave the doors open for a few minutes before entry.

Referring now to Figure 2 there is shown a refrigeration system which is generally identified by reference numeral 101. The refrigeration system comprises a container 102 which is adapted to be connected to a tractor unit (not shown).

A vessel 103 for holding liquid nitrogen is supported beneath the container 102 and is connected by a pipe 104 to a heat exchanger 111 which is in turn connected by a pipe 112 to a fan 113. A pipe 114 connects the fan 113 to a vent 115 above the container 102.

In use, when the temperature sensed by a probe 110 is higher than a predetermined level control valve 109 is opened to allow liquid nitrogen from vessel 103 (which is typically at 7-8 bar A) to pass along pipe 104 to heat exchanger 111 where it evaporates in indirect heat exchange with the air in the container 102. The gaseous nitrogen leaves the heat exchanger 111 through pipe 112 and is expanded through fan 113 which blows air through the heat exchanger 111 to enhance heat transfer and to ensure that the entire volume of air within the container 102 is substantially uniformly cooled.

As the nitrogen expands through the fan 113 its temperature drops slightly and further cooling of the container 102 is achieved by pipe 114.

The embodiment shown in Figure 3 is similar to that shown in Figure 2 and parts having similar features have

been identified by similar reference numerals in the 200 series. The essential difference in this embodiment is that the fan 213 is driven by the flow of liquid nitrogen en route to the heat exchanger 211. It will be appreciated that when cooling starts the flow in pipe 204 is essentially all gaseous. It then becomes two phase and eventually becomes substantially all liquid. This creates serious problems in designing fan 213 and, although feasible, this embodiment is not recommended.

The embodiment shown in Figure 4 is similar to that shown in Figures 2 and 3 and parts having similar functions have been identified by similar reference numerals in the 300 series.

In this embodiment the container 302 is a standard international freight container for refrigerated produce having an inlet port 316 and an outlet port 317.

An enclosure 319 is removably mounted on the container 302. The enclosure 319 contains a heat exchanger 311 and a fan 313. The fan 313 is a compact compander (compressor-expander) unit similar to the compander units used in air separation plant.

In a typical situation container 302 will be lifted off a container ship and secured to a land trailer having a vessel 103 filled with liquid nitrogen and enclosure 319 mounted so that inlet port 316 and the outlet port 317 of the container 302 abut the enclosure 319 as shown. Pipe 304 is then connected to the vessel 303 by a flexible coupling 320.

This embodiment provides a most effective way of distributing frozen produce from ship to shop with minimal delay.

The embodiment shown in Figure 5 is similar to that shown in Figures 2 and 3 and parts having similar functions have been identified by similar reference numerals in the 400 series.

In this embodiment liquid nitrogen from vessel 403 passes through pipe 404 to heat exchanger 411 where it evaporates and which it leaves through pipe 412. It is then work expanded through fans 413a and 413b. This expansion causes the temperature of the nitrogen to drop and it is carried from fan 413b through pipe 414a to heat exchanger 414b which it leaves through vent 415 which exhausts to atmosphere above the container 402.

The fans 413a and 413b draw air from the front end of the container 402 and blow it through heat exchangers 414b and 411 in which it is cooled. The air leaves the heat exchanger 411 through two distribution socks 421 which are porous and which help distribute the cold air throughout the container 402. The cold air is drawn back towards the inlet of the fans 413a and 413b and is recirculated until the desired low temperature is reached. At this time a thermostat 410 suitably located in the container 402 closes a valve to prevent further liquid nitrogen leaving vessel 403 until the temperature rises.

It will be appreciated that in each of the above embodiments the liquid nitrogen must be supplied under pressure. In the prior art this was effected by pressurising the vessel to between 1.5 and 2.0 bar (gauge) during filling and throttling the flow of liquid nitrogen into the container.

Referring to Figure 6, there is shown a vessel 503. The vessel 503 is provided with a pipe 504 for conveying liquid nitrogen to the inside of a container (not shown). A pipe 505 extends from the bottom of the vessel 503 to an evaporator 506 which has an outlet pipe 507 which is connected to the top of the vessel 503. A valve 508 is placed in the pipe 505 and can be opened and closed in response to a signal from a pressure sensor 509. A safety valve 510 is provided to vent should the

pressure in the vessel 503 exceed a predetermined value.

In use, vessel 503 is filled with liquid nitrogen at atmospheric pressure via a filler (not shown). The filler is then closed. Pressure sensor 509 causes valve 507 to open and liquid nitrogen to flow into evaporator 506. Ambient air vaporises the liquid nitrogen and the gaseous nitrogen thus formed passes through pipe 507 into the top of vessel 503. Since one volume of liquid nitrogen expands to approximately 700 volumes of gaseous nitrogen at atmospheric pressure the pressure in vessel 503 steadily increases until, at about 6 bar (gauge) the pressure sensor 509 completely closes the valve 508.

If the pressure in the vessel 503 increases excessively, for example due to heat ingress where no liquid nitrogen is being supplied the safety valve 510 opens to relieve the excess pressure. However, when liquid nitrogen is being drawn from the vessel 503 via pipe 504 the pressure in vessel 503 falls and pressure sensor 509 opens valve 508 to repressurise the vessel 503.

This arrangement has significant advantages over the prior art pressurising arrangement described above. In particular, the liquid nitrogen can be supplied to the inside of the container at a significantly higher pressure. In addition, the vessel 503 can be filled at atmospheric pressure which can be carried out more quickly than the prior art. Furthermore it is believed that more of the refrigeration in the liquid nitrogen will be available to the inside of the container.

If desired, the valve 508 could be positioned in the pipe 507.

The arrangement described in Figure 6 can be used in conjunction with any of the embodiments of the invention shown in Figures 2, 3, 4 and 5.

Claims:

1. A refrigeration system comprising a container, a vessel for holding liquid nitrogen, a fan for circulating air within said container, and a first heat exchanger, wherein said first heat exchanger is connected to said vessel and said fan is arranged to be driven by said nitrogen, and wherein means are provided to vent nitrogen externally of said container.

2. A refrigeration system as claimed in Claim 1, wherein said fan is arranged to be driven by nitrogen leaving the downstream end of said first heat exchanger.

3. A refrigeration system as claimed in Claim 2, including a second heat exchanger arranged to receive nitrogen from said fan.

4. A refrigeration system as claimed in Claim 3, wherein said fan is arranged to pass air through said second heat exchanger and then through said first heat exchanger.

5. A refrigeration system as claimed in Claim 1, wherein said fan is arranged to be driven by nitrogen flowing from said vessel to said first heat exchanger.

6. A refrigeration system as claimed in any preceding Claim, wherein said first heat exchanger is disposed within said container.

7. A refrigeration system as claimed in any of Claims 1 to 5, wherein said first heat exchanger is disposed in a separate enclosure communicating with said container.

8. A refrigeration system as claimed in any preceding Claim, including an evaporator, a pipe for conveying liquid nitrogen from said vessel to said evaporator, a pipe for conveying vaporised nitrogen from said evaporator to said vessel, and means for controlling the flow through said evaporator.

9. A refrigeration system as claimed in Claim 8, wherein said means comprises a flow control valve

operable in response to a pressure sensor mounted on said vessel.

10. A refrigeration system substantially as hereinbefore described with reference to and as shown in Figure 2 or Figures 3, 4, 5 and 6 of the accompanying drawings.

* * *

Patents Act 1977 Examiner's report to the Comptroller under Section 17 ıe Search report)	Application number GB 9402818.0
Relevant Technical Fields (i) UK Cl (Ed.M) F4H (ii) Int Cl (Ed.5) F25D	Search Examiner M C MONK Date of completion of Search 4 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- ALL

:ategories of documents

::	Document indicating lack of novelty or of inventive step.	P:	Document published on or after the declared priority date but before the filing date of the present application.
:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	E:	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
:	Document indicating technological background and/or state of the art.	&:	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1266216	(UNION CARBIDE) Expander 29: Vent 32a	1-7
X	GB 1242626	(UNION CARBIDE) see Figure 2	1-7
X	GB 1008905	(TRANSTHERMOS) see Figure 2	1-7

tabases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal tents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).